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Graphics and semantics: The relationship between what is seen and what is meant in icon design

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Abstract. Visual icons can be considered as a means for designers to convey messages to end-users via the interface of a computer system. This paper explores the relationship between the users' interpretation of icons and the meaning that designers intend icons to convey. Focussing on interface users' understanding of icons, recent research has shown that it is the closeness of the relationship between icon and function, known as the semantic distance, that is of prime importance in determining the success of icon usability. This contrasts with previous research which has suggested that the concreteness, or pictorialness, of icons is the key to good design. The theoretical and practical implications of these findings are discussed.

Keywords: Icons, Semantic distance, Concreteness, Semiotics

1 Introduction: Signs and Semiotics

Semiotics is the study of signs; it has, not surprisingly, been influential in assisting research on graphical user interfaces. De Souza [1] claimed that in addition to cognitively-based research, which focuses on an interface users' comprehension of signs and the consequent actions performed by those users, semiotic engineering can also play a part in providing guidance to designers. For instance, using the theoretical underpinnings of semiotics we can consider visual icon design as being a form of communication from the designer(s) to the user(s) via the interface of the computer system. Information that is designed to be communicated via a computer system will often occur in a different space and time to when the end-user operates the system. This means that unlike instantaneous human-to-human communication, the user is unlikely to be able to respond directly to the designer if they do not understand the message that has been sent [1]. The first stage of design is therefore to encode information into a signal which the user will be able to interpret, or decode [2].

In order to communicate information to users, interfaces frequently make use of pictorial and graphical objects, commonly referred to as icons. To develop icons for graphical user interfaces it is necessary to consider how they communicate information. In contrast to other writing systems, visual icons often communicate information in a non-verbal manner, not relying on syntactic or phonological rules to convey meaning [3]. Instead icons attempt to represent objects, concepts and functions by relying on the user's ability to learn the meaning of the icon using their pre-existing knowledge.

One of the founders of the field of semiotics, Charles Sanders Peirce [4], claimed that a sign is 'something which stands to somebody for something in some respect or capacity' (p. 135). According to Peirce signs are composed of three elements: 1) the Representamen (i.e. the representation); 2) the Object (i.e. the represented object, function or concept); 3) the Interpretant (i.e. the process of interpretation). This relationship is shown in Figure 1, using an example of an icon to represent the concept of being 'fast'. There is not necessarily a direct connection between the Object and Representamen [5]. In the example in Figure 1, an interpreter of the icon would have to recognise the hare that is depicted by the icon and have the knowledge that hares are fast-moving animals in order to arrive at the meaning of the icon ('fast').

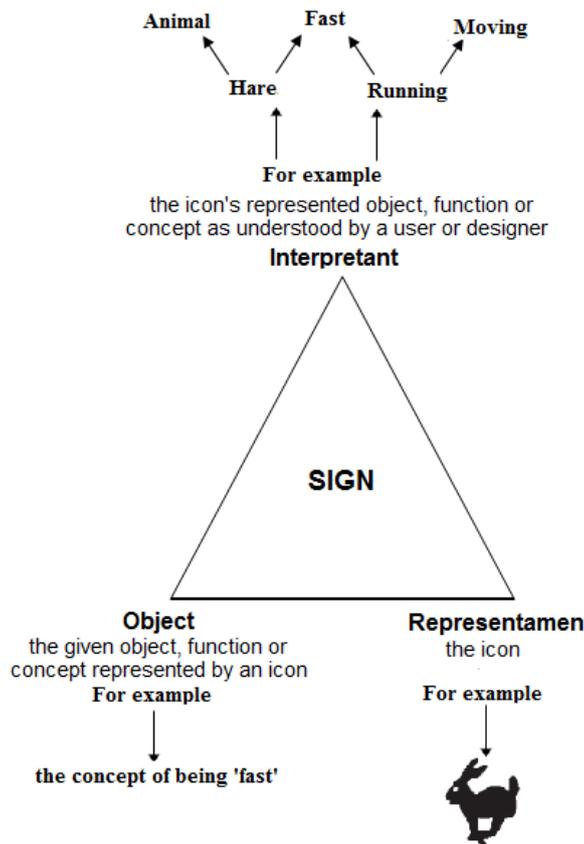


Fig. 1. Peirce's three elements of a Sign with the example of an icon representing the concept of being 'fast'

Peirce also believed that the Interpretant itself was a sign which could lead to other signs as interpretation was the process by which people associate meanings to signs. In other words, the more we think of an object, concept or function for instance, the more meanings we can associate to it. In Figure 1, the user could recognise the depiction of a hare and understand it as meaning animal, which then may lead to the meaning of mammal, and to leporid, and so on. It is not possible, however, to predict the amount of these meaningful associations [5].

When users interpret signs they do so uniquely; each user will have their own culture, knowledge, familiarity with the sign or its depicted function, frequency of use of the sign and so on. This means that it is not easy for the designer to determine the relationship between the Interpretant and Object for each interface user 'since it is an inherent function of the person (Interpretant) or culture' [6] (p. 742). It is therefore crucial that the designer considers who the end-users of a system are going to be with regard to their likely culture, knowledge and frequency of use of the icon. For instance, will the users understand the cultural codes used by the designer to communicate a certain message? Indeed both the end-users and the designer will have their own sets of acquired mental models relating to the knowledge and experiences they have gained during their lifetimes, and the culture that they belong to [7].

The choice of icons that are used to represent information for a specific computer system will ideally activate accurate mental models in the end-users. Faulkner [8] claimed that the computer interface must facilitate users in developing accurate mental models of the computer system, as it is these mental models that the users employ to understand how the system works. These models are likely to evolve as novice interface users recognise some element of the icon which allows them to understand its meaning or function (for instance a hare is recognised as a fast-moving animal in Figure 1 leading to the deduction that the icon means 'fast'), or experienced users recognising the icon and its function through repeated exposure with it (the icon in Figure 1 is simply recognised as 'fast'). How the user interprets the sign will depend on the user's mental models, likewise how the designer chooses to represent the object may also depend on their own set of mental models (see Figure 2). It is

important to note that the function assigned to an icon by those designing it may be quite different to the meaning attributed to it by users in practice. Ideally the link between the Representamen and Object should be obvious to all using the interface and so lead to just one Interpretant. It should activate the correct mental model which allows the users to not only understand the function of an icon but also act on it appropriately.

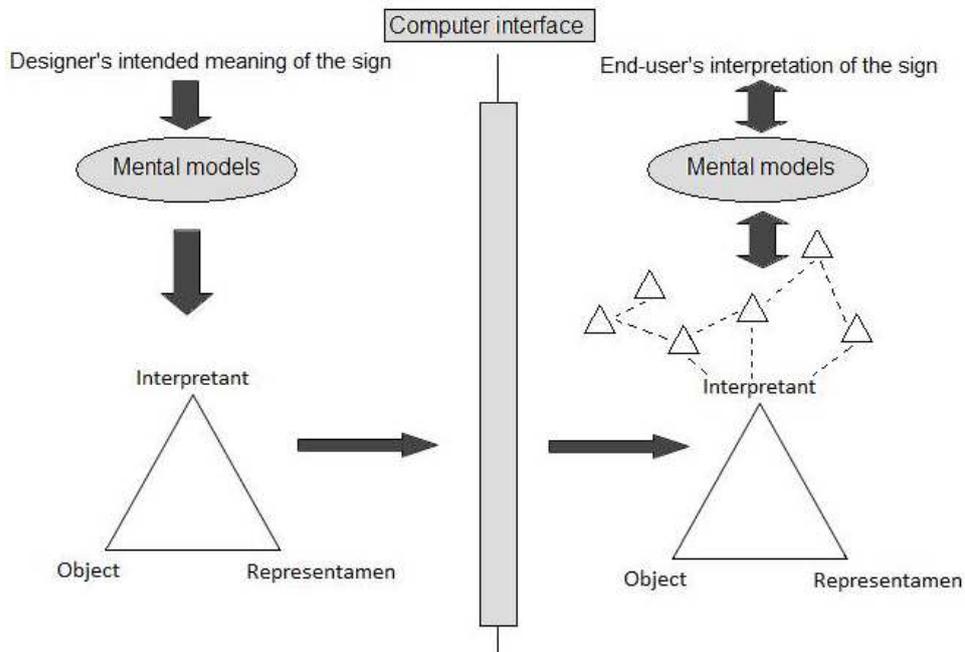


Fig. 2. Sign interpretation of a designer and an interface user

2 Icon Concreteness

In order to try and make the relationship between the Object and Representamen obvious icons may be designed to be pictorial representations of the objects they are depicting (i.e. concrete icons, see Figure 3 a and b). Concrete icons are thought to be easy to interpret as they allow people to apply their everyday knowledge, about the objects depicted by them, in order to make inferences about the function of the icon [9]. In contrast, abstract icons are likely to represent information using graphical features such as arrows and lines and consequently have less obvious connections with their real world referents (see Figure 3 c and d). In practice a user applying their everyday knowledge to a symbol would be likely to easily infer the meaning or function represented by a concrete symbol without needing any explicit learning of the icon as they should contain what we already know about everyday objects; whereas abstract icons are more likely to require training. Research has shown that users respond more quickly and accurately to concrete icons than to abstract icons, thus supporting the idea that a pictorial or visually obvious symbol will be most easily understood by a user [10], [11], [12], [13], [14]. However other experiments have found that such performance advantages diminish over time when users are allowed to gain experience with a set of icons [15], [16], [17]. Therefore, for interfaces that are likely to be used frequently, the initial advantages of concrete symbols will decline as users learn the meanings of the abstract symbols. It is interesting to note that although users prefer concrete symbols to abstract symbols [18], [19], [20], this is not always reflected in a user's performance. Stammers [19] found that even when users preferred concrete icons for a function, they did not always respond more quickly or accurately than they did with abstract icons.

3 Semantic Distance

3.1 Semantic Distance and Concreteness

Not everything that needs to be represented on an interface will refer to items, such as simple objects, that are easy to depict concretely. A number of studies have found that as objects, concepts or functions to be represented become more abstract they can become more problematic to depict pictorially [11], [21]. However, concreteness is not the sole determinant of ease of access to meaning. Semantic distance is the term used to refer to the closeness of the relationship between the icon and what it is intended to represent. This relationship can also be used to determine icon usability and may be either close or distant for both concrete and abstract icons. For instance, both Figure 3a and Figure 3c have direct relationships between the icon and the function they represent, despite the fact that one is concrete and the other is abstract. Similarly, Figure 3b and Figure 3d have a less obvious, more distant, relationship between icon and function. Interestingly, McDougall et al [22] examined users' responses to icon sets in which the icon characteristics of semantic distance and concreteness were varied. They found that semantic distance was a stronger determinant of performance than concreteness.

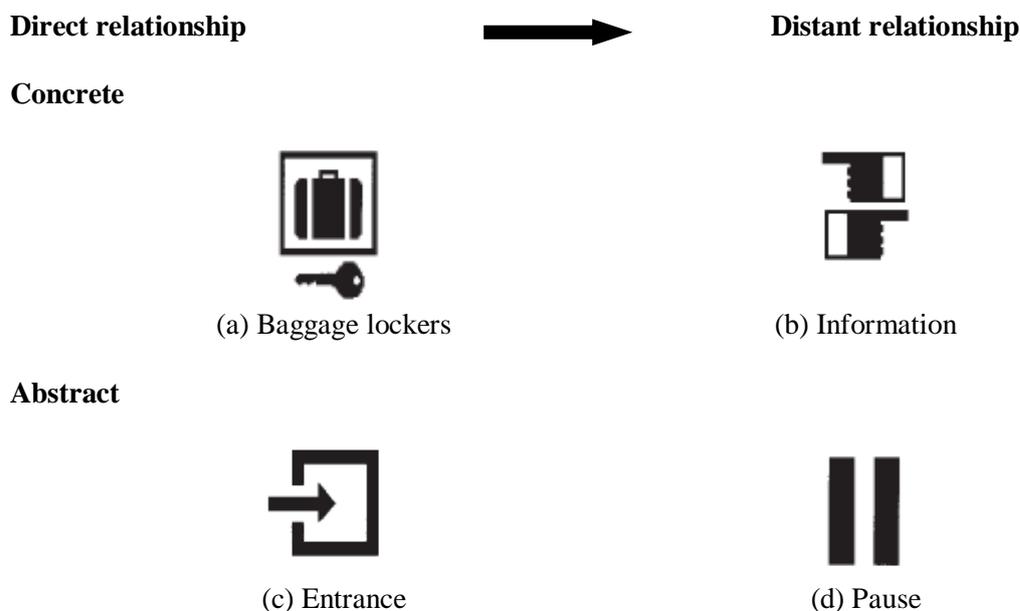


Fig. 3. Icon-referent relationships

3.2 Semantic Distance as a Continuum

Although the word 'icon' is now commonly used to refer to the pictorial and graphical objects used to communicate information (and used interchangeably with the words 'symbol' and 'sign' in this report) it was a term given a more specific description by Peirce in his taxonomy of signs. Peirce classified signs into 3 categories, icon, index and symbol.

1. A sign in the icon category represents an object because it pictorially resembles the object.
2. Signs in the index category refer to the object they represent because they are affected by that object. For instance Moyes and Jordan [9] give an example of the association between smoke and fire as smoke can be used as a sign to imply the existence of a fire.

3. Finally symbols have an arbitrary relationship with the object being symbolized. There is no connection between the symbol and its real world counterpart. Arbitrary symbols therefore 'represent objects by virtue of a rule or convention' [23] (p. 70).

This taxonomy describes a similar dimension to that represented in the concept of semantic distance. Where, in the first instance there is a close, direct, relationship between the icon and its intended function; the second type requires the use of inferences in order to ascertain the meaning of the icon; and the third level consists of arbitrary relationships in which the function of the icon is understood only if users have previously learned its meaning. In practice it is possible to regard this dimension as a continuum running from very closely related to very distantly related [24].

3.3 The Importance of Semantic Distance

The evidence available suggests that semantic distance has an important role to play in determining interpretability [6], [16], [22], [25]. For instance, Isherwood et al [16] examined the relative importance of icon characteristics (including semantic distance, concreteness and familiarity amongst others) in determining the speed and accuracy of icon identification as users gained experience with icons. Icon characteristics were found to account for up to 69% of the variance observed in user performance and semantic distance was initially found to be the primary predictor of user performance. It was thought that this potentially reflected the users' learning of icon-function relationships. The importance of semantic distance, particularly for novice icon users, suggested that the effects of the visual metaphor employed in concrete icons were less powerful than is commonly supposed, possibly because only a limited number of functions can easily be represented pictorially [11], [13]. Many more concepts can be represented abstractly than pictorially and so icon design should perhaps focus more closely on this conceptual mapping between icon and function rather than relying on concrete icons.

The importance of semantic distance may be related to the fact that it is a measure of the degree to which icon and function labels are related. Familant and Detweiler [2] claimed that the simplest type of icon-referent relationship is one where the signal denotes just the one referent (a direct sign relationship). This occurs whether or not the icon is a direct visual metaphor or an abstract representation of its referent. Hence it is the relationship between the signal and referent which is of importance rather than concreteness per se.

The importance of 'goodness-of-fit' also seems to be significant for picture naming, and where a number of names are possible, this creates uncertainty and slows semantic access and naming response times [26], [27]. Three types of stored representations are thought to be involved in object naming: visual, semantic, and lexical representations. Each form of representation is usually associated with a series of processing stages. A theoretical model developed by Johnson et al [27] outlined the following processing stages: 1) search and perception of the picture, 2) retrieval of a matching representation (i.e., stored visual representations), 3) activation of semantic information (i.e., conceptual and functional information associated with the object), 4) access to the function, or name, via referential connections. It is possible that semantic distance is an index of the closeness and efficacy of the connection between visual, semantic and lexical representations

4 Familiarity

In addition to the strength of icon-referent relationships Isherwood et al [16] and McDougall and Isherwood [25] also found familiarity to be an important predictor of user performance with icons. As users gained experience with the icons in these studies familiarity with an icon, and with the function of an icon, became important predictors of performance. McDougall and Isherwood [25] argued that the importance of familiarity, with both the icon and function, suggests that they have longer term effects in determining response times because of familiar items being easier to access in long-term memory representation even after a number of repeated presentations. These authors suggest that, with regard to the processing stages outlined by Johnson et al [27] icon familiarity may be an index of

the ease with which individuals can access stored visual representations and may even help drive initial semantic access.

In addition to exploring the determinants of icon usability these studies have also shown that the primary predictors of performance change as users gained experience with the icons. Strong icon-referent relationships were of initial importance whereas icon function and familiarity become more important to experienced icon users. Icons are often not known and have to be learned initially but this is not the case once users have become experienced at using the icons. It is therefore not surprising that, predictors of icon identification change as learning occurs [15], [16], [17].

5 Conclusion

In order to allow the continuing advancement of user controlled systems the users involved in human-computer interaction must be better understood. How information can be communicated from one person to another through the use of icons is often less straightforward than simply relying on pictorial associations with the icon's referent. As noted by Familant and Detweiler 'objects called icons, even if restricted to icons in a computer environment are far more diverse and their relationships to the objects and events they are intended to represent far more complicated, than one might suppose' [2] (p.705). This report has attempted to advocate the consideration of the signal-referent relationship in icon design and to take into account the importance of the end-users' input into the icon's interpretation. Icons that are well-mapped to their referents and have been designed with consideration to the end-users (whether visual or auditory icons, for instance see [28], [29]) should be unambiguous in their intended meaning and consequently clearly understood and acted on appropriately by users. Good interface design should ideally produce a limited amount of meanings for a given message, without limiting the uses or functions of the computer system [1].

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